PARTICIPATORY DISCREPANCIES AND THE PERCEPTION OF BEATS IN JAZZ

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A popular theory holds that “swing” stems specifically from asynchronous timing between bass and drums in their shared articulation of the beat, a phenomenon Charles Keil has dubbed “participatory discrepancies” (PDs; Keil, 1987). The “push and pull” between these instruments purportedly generates a “productive tension” thought to drive the groove with energy. This paper presents the results of two experiments on the perception of PDs. Experiment 1 employed synthetic recordings of a conventional swing groove in which the onset asynchronies between bass and drums were varied. Participants used three listening strategies to perceive the asynchrony and its purported effects. Experiment 2 employed recordings of professional jazz musicians and tested for the effects of learning in the perception of PDs. Little evidence emerged from either experiment in support of the PD framework. An alternative proposal drawn from metric entrainment theory explains the effects of PDs as more limited and local than previously thought.

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There is no essential groove, no abstract time, no “metronome sense” in the strict sense of metronome, no feeling qua feeling, just constant relativity, constant relating, constant negotiation of a groove between players in a particular time and place with a complex variety of variables intersecting millisecond by millisecond. Abstract time is a nice Platonic idea, a perfect essence, but real time, natural time, human time, is always variable.


In 1966, ethnomusicologist Charles Keil proposed a novel framework for understanding the nature and production of the mysterious rhythmic quality known as swing. Keil offered the term “engendered feeling” to refer to the processual, emergent qualities of musical emotion he found in jazz rhythm. Formulated in opposition to Leonard Meyer’s (1956) concept of “embodied meaning,” Keil sought to capture with the term a crucial aspect of jazz performance practice, that certain something beyond notation that performers add to music to make it swing.1 Engendered feeling is essentially a more general term for swing, groove, or what Andre Hodeir called “vital drive” (1956, pp. 207-209); it evokes the impulse that makes music come alive and induces listeners to movement, to a feelingful, corporeal participation in the ebb and flow of a given performance.

Engendered feeling, Keil suggested, is produced by “pulling against the pulse” (1966, p. 341). It emerges specifically from asynchronous timing at the microrhythmic level within an ensemble, a phenomenon he latter dubbed “participatory discrepancies,” or PDs: “It is the little discrepancies within a jazz drummer’s beat, between bass and drums, between rhythm section and soloists, that create ‘swing’ and invite us to participate” (Keil, 1987, p. 277). Music, insisted Keil, must be “out of time to groove,” for “PDs are where the juice, the groove, the funk, and the delights of music, and of life, are” (Keil & Feld, 1994, pp. 155, 171), and their effects inspire listeners to “get up and dance because the music is so contagious” (Keil, 1995, p. 2).

Though many timing relationships exist within any ensemble, most studies of microrhythmic processes in jazz to date have focused primarily on two dimensions: (1) the “swing ratio,” which expresses the durational relationship between the long downbeat eighth note and the short upbeat; and (2) asynchronous timing between bassists and drummers in the articulation of an ongoing beat.2 The expressive quality of a soloist’s particular style of swing is believed to stem largely from


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the former; but swing as an emergent quality of groove—the feeling that gets feet tapping and heads bobbing—is thought to result specifically from the “tension” generated between bass and drums as they negotiate the beat. Typically, one plays ever so slightly ahead of the other—that is the “discrepancy”—and the push and pull between them purportedly produces the effect of swing.

In the four decades since Keil first speculated about engendered feeling, a growing consensus seems to have emerged around the PD model. Numerous empirical studies have verified the existence and systematic character of PDs, which suggests that they are more than random accidents of imperfect timing on the part of very human musicians. Moreover, ethnographic inquiry into jazz rhythm has suggested the centrality of timing for jazz musicians’ concepts of swing with frequent discussions of playing “on top of” or “laying back” on the beat (Berliner, 1994, pp. 150-152, 245, 351-352, 396, 413; Keil, 1995, p. 8; Monson, 1996, p. 56). Clearly, the PD model has become the prevailing paradigm for explaining the nature and production of swing.

We should not be surprised to find that timing discrepancies exist in music, of course. “For a number of reasons,” writes Rudolf Rasch, “such as the restricted accuracy of human motor performance and time perception, the relative ease of tone production within or between instruments, and the time lag between the production of a player’s own tones and the perception of the tones produced by others, a perfect synchronization is not possible in a live performance. There will always be some degree of asynchronization” (1988, p. 71). No one, however, has presented any evidence that asynchronies between bass and drums in the articulation of the beat are actually available to human perception, much less that they do in fact generate the rhythmic quality we call swing. It seems rather that Keil, Prögler, and others have simply assumed the expressive power of participatory discrepancies as a matter of faith, without evidence of their tangible effects.

In a widely cited study, Hirsh (1959) found that humans require a minimum asynchrony of 2 ms to perceive successive tone onsets under ideal laboratory conditions, but at least 20 ms between onsets to perceive which of two contrasting sounds comes first. More recently, empirical studies of jazz rhythm have revealed that the timing discrepancy between bass and the drummer’s ride tap typically lies right around this 20 ms threshold. Friberg and Sundström (2002) showed an average discrepancy of less than 20 ms between bass and ride cymbal onsets across a range of tempos on recordings of bassists Ron Carter, Robert Leslie Hurst III, and Gary Peacock (p. 343, Fig. 8).

Similarly, in a detailed study of timing relationships on a Jamey Aebersold “Play-A-Long” record, Rose (1989) found that “mean latency values” among rhythm section instruments were generally within approximately 20 ms of one another. Studies of temporal acuity and the just noticeable difference (JND) in onset orders led Rose to conclude that “onset time differences of 20 ms or less are unlikely to be perceived when they occur in musical or ‘pseudo-musical’ settings” (p. 113).

In general, then, most listeners will likely perceive ride cymbal and bass onsets as simultaneous unless the gaps between them grow too large, leading to interpretation as errors in timing. But listeners’ inability to detect the discrepancy or determine which instrument comes first does not necessarily invalidate the claims of PD theory. Brown and Dempster (1989) have argued persuasively that “the theoretical structures, events and processes referred to in all music analyses need not be directly hearable by anyone, not even the most refined and sensitive analyst. All that is required is that sooner or later, directly or indirectly, the theoretical entities postulated in analyses contribute to an explanation of musical events that are hearable” (p. 96). Analogously, we might argue that listeners’ inability to detect participatory discrepancies directly is immaterial; all that matters is whether or not their effects are available to perception. Thus, for example, at issue in Palmer’s research on onset asynchronies in piano performance is not whether listeners can determine which note in a chord is struck first, but whether such asynchronies contribute to auditory stream segregation and thereby facilitate perception of the melody in the context of a timbrally undifferentiated texture (Palmer, 1989, 1996). Similarly, if it is indeed “the gaps, large or small, which provide the push or layback feel of a particular performance,” as Prögler claims (1995, p. 34), listeners should be able to identify not so much the gaps themselves as their effects in terms of the “push or layback feel” they are thought to produce.

This study presents the results of two experiments on the perception of PDs and their purported effects. Participants were presented with recorded excerpts in which the asynchrony between bass and drums was systematically varied. Three listening strategies were employed to determine whether PDs or their effects could be discerned, and as will be seen, little evidence in support of the PD model emerged. This, I suggest, weakens the claim of PD theory that swing stems from asynchronous timing between bass and drums. Their effects, I shall propose, are more limited and local than presently construed within PD theory.
Experiment 1

This study was undertaken to determine whether or not timing discrepancies between bass and drums in the articulation of an ongoing beat do indeed generate “a productive tension . . . which is central to swing,” as assumed in PD theory (Prögler, 1995, p. 22). This is not simply a matter of asking individuals to evaluate the degree of swing in musical excerpts with varying timing profiles, however, for swing has never been defined narrowly enough such that an objective, quantitative measure could be taken. Consequently, the experiment detailed below tested for two things: (1) the perceptual salience of PDs within the range of expressive nuance—i.e., before the gaps between bass and drums grow too large and are consequently interpreted as errors in timing; and (2) their putative effects—effects that presumably characterize a groove that jazz musicians and their audiences would define as swinging. More specifically, the instrument leading—i.e., playing “on top” of the beat—should be heard in terms of “push,” i.e., it should be perceived as driving the groove.

Method

Participants were undergraduate students enrolled in either a music fundamentals course or an interdisciplinary course on time and rhythm. Three groups of participants were each instructed to employ a different listening strategy, as detailed below. There were 22 participants in the first group, 19 in the second, and 22 in the third.

Participants ranged in music background from none at all to as many as 14 years of private instruction and ensemble performance experience. Most listed “rock” as their favorite style of music on a preliminary background questionnaire, though about one third listed jazz among their top two. These factors appeared to have little bearing on the results, however. A Pearson product-moment correlation comparing correct scores and years of formal training showed little or no relationship [Group 1: \( r(20) = .05 \); Group 2: \( r(17) = .08 \); Group 3: \( r(20) = .06 \)], the same was true when comparing correct scores with stylistic preference [Group 1: \( r(20) = .11 \); Group 2: \( r(17) = .05 \); Group 3: \( r(20) = .07 \)]. Consequently, these factors have been disregarded in the analyses that follow.

Procedure

Participants heard a series of synthetic samples (created by the author) of bass and drums playing a standard swing groove. Each sample consisted of one chorus of a 12-bar blues progression in G major in common time featuring a walking bass line accompanied by the ride rhythm played on the ride cymbal with the hi-hat snapped shut on beats 2 and 4, a brief excerpt of which is shown in Example 1.

The samples were generated with the music notation software program Sibelius using the “rubato meccanico” and “heavy swing” settings. The former provides performance playback in strict time with no rubato—in other words, it is a “mechanical” performance with respect to tempo. The latter applies to the swing ratio—the relationship between the long downbeat and short upbeat eighth note of a swing-eighth pair. Heavy swing, in Sibelius, entails a high ratio and thus a more uneven, “triplety” relationship between downbeat and upbeat. By contrast, the light swing setting entails a lower ratio and thus more even eighth notes. The heavy swing setting was chosen for this experiment because empirical studies have shown that drummers tend to play with a higher swing ratio than soloists (Collier & Collier, 1996b; Friberg & Sundström, 2002; Honing & Haas, 2008; Rose, 1989).

Three tempos were employed in the synthetic samples: 135 bpm, 160 bpm, and 208 bpm. At each tempo,

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**Example 1.** Excerpt of synthetic sample employed in Experiment 1, created in Sibelius. Measures 1-4 of a 12-bar blues progression in the key of G is shown. Walking bass line is accompanied by the ride rhythm performed on the ride cymbal with the hi-hat snapped shut on beats 2 and 4. Eighth notes are swung—i.e., played unevenly, with the downbeat eighth note longer in duration than the upbeat.
the downbeat timings of each instrument were varied by adjusting their “tick” values (1 tick = 1/256th of a beat) to produce asynchronies of approximately 10, 20, and 30 ms between their onsets, keeping them consistently “in sync but out of phase” (Feld, 1994, p. 119). Thus, for each tempo, participants heard three “performances” with bass leading (10, 20, and 30 ms), three with drums leading (10, 20, and 30 ms), and one where the timing was left in sync, making seven samples at each tempo for a total of 21.

The specific asynchronies were chosen around the 20 ms threshold identified by Hirsh (1959) as the minimum temporal discrepancy required for humans to perceive the order of two consecutive but contrasting sounds and because 20 ms has been shown to be a fairly common discrepancy between ride cymbal and bass onsets in the jazz rhythm section, as discussed above. At a 10 ms discrepancy, accordingly, participants should be unable to determine whether the bass or cymbal struck first. At 20 ms, they should have marginally more success, and still more at 30 ms. Discrepancies above 30 ms were not used in this experiment because, it was judged, they tend to sound disjunct, unnatural, and more like errors in timing than expressive deviations from synchrony.

Sample length ranged from 15-25 s depending on the tempo. The samples were presented to participants in random order in three sets of seven with a between-stimulus interval of about 30 s and a between-set interval of 2-3 min. They were played over a standard stereo system at a fairly loud but not uncomfortable volume (65-75 dB) in a college classroom. Participants were asked to circle either bass or drums on a form in accordance with the instructions after they heard each sample. Each complete test session lasted no more than about 25 min.

Three groups of participants were instructed to use different listening strategies. The first group of participants was informed that the downbeat timings between the instruments would vary. They were instructed to listen specifically for timing on each beat and to indicate which instrument they believed tended to come first.

The second group was instructed to employ an alternative listening strategy. They were told nothing of the timing discrepancies between the instruments. Instead they were told that one instrument would tend to sound “more assertive, as though leading the other in a dance,” while the other instrument would sound “more passive and relaxed, as though following.” They were instructed to determine which instrument sounded more assertive. Instead of gauging listeners’ ability to detect timing discrepancies explicitly, this was intended to ascertain if they could perceive the effects hypothesized by PD theory: the instrument leading should be heard in terms of “push,” as driving the groove—as being more “assertive.”

A third group of participants was given combined instructions: they were told of the timing discrepancies and that the instrument that played “on top”—i.e., just ahead of the other—would tend to sound more assertive, while the other instrument would tend to sound more passive. In other words, they were asked to combine the timing and assertiveness strategies employed by the first two groups. This was intended to determine if listening for timing in terms of the expressive effect it is thought to produce facilitates perception of the discrepancy. Participants were again instructed to determine which instrument tended to lead—which one was presumably more assertive in keeping the time.

Results

The results were analyzed by a four-factor mixed-design analysis of variance (ANOVA) with repeated measures for the factors of tempo, instrument, and asynchrony width, and between groups for listening strategy instructions. The ANOVA showed no significant main effects or interactions, but listening strategy approached the decision criterion of significance, $F(2, 60) = 1.91$, $p = .16$. In particular, pairwise comparisons showed that participants who were instructed to listen for both timing and assertion together (Group 3) performed better than those who employed either timing alone ($p = .10$) or assertion alone ($p = .10$), as can be seen in Figure 1 (chance performance gives 50% correct). This prompted a closer look at the data for Group 3.

![Figure 1](http://online.ucpress.edu/mp/article-pdf/27/3/157/190522/mp_2010_27_3_157.pdf)
A t-test confirmed that the 54% group average score for the "both" strategy (Group 3) was significantly better than chance when all asynchrony values were combined, \( t(21) = 1.95, p = .03 \) (one-tailed), indicating a modest overall ability to recognize the asynchrony. Consequently, a second ANOVA was conducted with repeated measures for the factors of tempo, instrument, and asynchrony width on the data for Group 3 alone.

Figure 2 shows the average scores for Group 3 at each asynchrony value, irrespective of tempo and instrumentation. We should expect perception of the lead instrument to improve as the asynchrony widens, and the data in Figure 2 appear to support this hypothesis. Though the \( t \)-test indicated a significant overall effect of the asynchrony for Group 3, the degree of asynchrony nevertheless lacked significance: the ANOVA showed no significant main effect of asynchrony width, \( F(2, 42) = 0.29, p = .75 \). Participants did not perform statistically better as the asynchrony was increased.

There was, however, a significant effect of instrumentation, \( F(1, 21) = 9.85, p < .01 \): participants identified drum leads correctly at an average rate of 60.1%, but bass leads at a rate of just 48.0%. There was also a significant interaction between instrument and tempo, \( F(2, 42) = 4.44, p = .02 \). As shown in Figure 3, success identifying drum leads increased significantly with tempo, whereas accuracy for recognizing bass leads dropped substantially at 208 bpm.

The effect of instrumentation, especially at the fastest tempo, suggests the presence of a perceptual bias in favor of drum leads. Consequently, the responses for the zero-asynchrony condition were examined to estimate false-alarm rates in order to evaluate bias and sensitivity. False-alarm rates showed no bias for drums or bass leads for the timing and assertion strategies, but a strong bias emerged when listening for both together. A Z-score analysis was used to normalize and compare the false-alarm rates and hit rates for each instrument for Group 3, the results of which are presented in Table 1. Estimated bias is measured from false-alarm rates \( [p(FA)] \), which indicate the frequency at which each instrument was selected as leading when there was no onset asynchrony. Correct scores \( [p(Hits)] \) show the frequency at which each instrument was correctly identified as leading at any asynchrony value. Estimated sensitivity (\( \Delta \)) measures the difference between false-alarm and hit rates, and Z-scores \( [(\Delta - 0)/SD] \) indicate normalized measures of sensitivity to the asynchrony.

Three groups of comparisons are shown in Table 1: (1) those for all participants using this strategy; (2) those for the three participants with the highest scores; and (3) those for all participants except the top three. The average scores of individual participants in Group 3 were generally within chance levels (50%). But the top three, distinguished from their peers neither by music training nor a stylistic preference for jazz, scored 72.2% (13/18). A binomial test indicated that this score was not likely the result of chance \( (p = .03) \). Similar success was not seen among the participants in Group 1, where only one of twenty-two individuals scored above 70%, nor in Group 2, where none of nineteen individuals did so. Thus, it appears that a small number of individuals (about 14% in this study) can potentially identify the lead instrument with some facility, but only when listening for both timing and assertion together.

As can be seen from Table 1, participants who received combined listening instructions (timing and assertion together) exhibited a significant false-alarm rate for
drum leads, but not for bass leads—i.e., when no asynchrony was present, they reported drum leads 79% of the time. By contrast, the hit rate for bass improved when there was an actual asynchrony. This indicates a general bias toward hearing drum leads over bass when using this listening strategy, but a greater sensitivity to bass leads when an actual asynchrony was present.

The top three participants were especially sensitive to bass leads ($Z = 1.77$). It appears that they worked from an assumption that drums were leading and entrained primarily to the pulse provided on the ride cymbal, against which they compared the timing of bass onsets. They then selected drums unless a bass lead seemed apparent.

The remaining participants also showed greater sensitivity to bass leads than drums, but to a lesser degree ($Z = 0.72$). Though they showed about the same bias towards perception of drum leads over bass in the zero asynchrony condition as the top three, they were dramatically less successful at actually identifying drum leads when an asynchrony was applied ($Z = -0.65$). This suggests that either the top three participants simply possessed a greater perceptual acuity for temporal discrimination, or they employed the most coherent listening strategy.

**Discussion**

Only modest conclusions about the effects of PDs can be drawn from this experiment. For the purposes of identifying a discrepancy between bass and drum onsets, listening for assertion and timing together was generally more effective than listening for either timing or assertion alone. There was a small overall effect of the asynchrony for listeners who employed the "both" strategy. That is, their average score in identifying any asynchrony from 10-30 ms was significantly better than chance, although the magnitude of this effect was small. The degree of asynchrony within this range did not seem to provide a significant advantage, however. Further analysis comparing false-alarm and hit rates showed that responses were strongly biased toward drum leads when no onset asynchrony was present. While demonstrating greater sensitivity to bass leads than drums, most participants were nevertheless unable to identify them consistently—their scores rarely exceeded chance levels.

Even at their best, participants perceived bass or drum leads at levels barely exceeding chance. Most listeners simply are not able to identify a discrepancy of 30 ms or less with any degree of consistency, no matter the instrument, tempo, or listening strategy. A few, however, do appear to have some success with this when they know specifically what they are listening for—i.e., both timing and assertion together. This might result from a greater perceptual acuity for temporal discrimination among these individuals, or from a more coherent listening strategy. Nevertheless, the poor performance of the group overall suggests that the asynchrony is simply not a very robust phenomenon.

**Experiment 2**

The synthetic samples employed in Experiment 1 allowed for experimental control of the discrepancy between bass and drum onsets. This control came at the expense of ecological validity, however, since real musicians are not generally able to remain so consistently “in sync but out of phase.” Consequently, a second experiment was conducted using a series of examples drawn either from commercially available recordings or...
from Jamey Aebersold “Play-A-Long” records with the piano part filtered out. The experiment sought to determine two things: First, do individuals fare any better in perceiving the discrepancy with recordings of professional jazz musicians than with synthetic examples? And second, do individuals perform more effectively when they hear an excerpt multiple times—in other words, what is the effect of learning?

**Method**

**PARTICIPANTS**

Participants consisted again of undergraduate students enrolled in an interdisciplinary course on time and rhythm, not generally different from the participants used in Experiment 1. The 22 individuals who took part in this experiment ranged in music background from none at all to 12 years of private instruction and ensemble performance experience. Most indicated a stylistic preference for “rock” music, though once again, about one third listed jazz among their top two preferred styles. Again, however, these factors proved largely irrelevant to participants’ performance in the experiment. A Pearson product-moment correlation comparing correct scores and stylistic preference showed only a weak relationship, $r(20) = .29$. The same was true when comparing correct scores with music background, $r(20) = -.20$; formal music training, it appears, presented no advantage in this study. Consequently, these factors have been disregarded in the analyses that follow.

**PROCEDURE**

The recordings used in the second experiment are listed in Table 2. Average lead times for each recording, shown in the column furthest to the right, were all of similar magnitudes, ranging from 15-19 ms, whether for bass or drums. These were calculated from careful estimates performed by the author of the onset asynchronies between bass and drums for each downbeat based on waveform analysis using the software program Audacity. Specific excerpts were chosen because they consisted only of bass and drums in order to eliminate complexity from other instruments and because the recording quality was high enough to discern onsets with clarity. Wave envelopes for each beat were then scanned visually to identify the basic profile for cymbal and bass onsets, whose shapes are quite recognizable, as can be seen from the screenshot of a beat onset shown in Figure 4. Cymbal strikes in particular tend to be well defined and easy to spot—they appear “furry.” Bass onsets, by contrast, are characterized by a substantial burst in wave amplitude. They are not as clear as cymbal strikes, however, and this required formulation of a consistent procedure to define them.

To this end, determination of each bass onset would begin with an onset hypothesis, placing it tentatively at the peak of the first wave whose amplitude departed significantly from the prevailing shape preceding it. A careful aural analysis of the beat ensued, working backwards and forwards from that point and adjusting it in accordance with aural evidence for an earlier or later onset until it could be determined with confidence to within ±5 ms. Any beat where the bass onset could not be determined with confidence to within this interval was omitted from analysis.

The average lead times shown in Table 2 are thus close approximations that nevertheless reflect the timing

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**FIGURE 4.** Screenshot of the wave envelope at the onset of a beat, drawn from Sonny Rollins’s “Blue 7,” generated by Audacity. The onset of the drummer’s hi-hat cymbal (dr: hh) appears “furry,” whereas the bass onset (bs) is characterized by a rapid burst in amplitude.
tendencies of each recorded excerpt. Figures for lead instrument in Table 2 are accurate, however, as it was relatively easy to identify which onset came first. In “Abdullah’s Delight,” timings were taken in relation to the hi-hat backbeats since the ride cymbal was absent on beats 1 and 3.

Because listening for timing and assertion together was the most successful strategy in Experiment 1, participants in Experiment 2 were asked to determine which instrument tended to strike the beat first and to listen in terms of assertion or passivity. They were instructed to circle either bass or drums on the form provided as they listened to each excerpt. Recordings were played over a standard stereo system at a loud but not uncomfortable volume (65-75 dB) in a college classroom. The duration of each recorded excerpt ranged from about 25-45 s. They were presented to participants in random order in three sets of five with a between-stimulus interval of approximately 30 s and a between-sets interval of 2-3 min. The entire test was completed in less than 25 min.

Table 3 shows the percentage of correct responses for identifying the leading instrument in each hearing of the recorded examples. Average scores for each excerpt were all over 50%, but less than 60%. A $t$-test nevertheless revealed that the group average score (55.15%) was not significantly better than chance, $t(21) = 1.57, p = .13$. A two-factor repeated measures ANOVA found no significant effect of recorded excerpt, $F(4, 84) = 0.24, p = .92$, nor trial, $F(2, 42) = 0.16, p = .85$, and no significant interaction between them, $F(8, 168) = 1.40, p = .20$. Participants’ scores did not improve significantly with repeated hearings, and there was no significant difference on their performance with any particular recorded excerpt. It appears, then, that they performed no better than chance for any of the excerpts and that there was no effect of learning.

Two findings were nevertheless of interest here. First, neither bass nor drums enjoyed an advantage over the other. By contrast with Experiment 1, average scores for

<table>
<thead>
<tr>
<th>Song</th>
<th>Album</th>
<th>Bassist</th>
<th>Drummer</th>
<th>Tempo</th>
<th>Lead instrument</th>
<th>Approximate average lead time</th>
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<tbody>
<tr>
<td>Bass lead</td>
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<tr>
<td>1. “Tune Up (Fast)”</td>
<td>Jamey Aebersold,</td>
<td>Tyrone Wheeler</td>
<td>Steve Davis</td>
<td>244 bpm (246 ms/beat)</td>
<td>Bass (60.5%)</td>
<td>15 ms</td>
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<td></td>
<td><em>Volume 7 – Miles Davis</em></td>
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<td>2. “Work Song”</td>
<td>Jamey Aebersold,</td>
<td>Sam Jones</td>
<td>Louis Hayes</td>
<td>199 bpm (302 ms/beat)</td>
<td>Bass (76.4%)</td>
<td>16 ms</td>
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<td><em>Volume 13 – Cannonball Adderley</em></td>
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<tr>
<td>Ride cymbal lead</td>
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<tr>
<td>3. “Blue 7”</td>
<td>Sonny Rollins,</td>
<td>Doug Watkins</td>
<td>Max Roach</td>
<td>132 bpm (455 ms/beat)</td>
<td>Drums (91.0%)</td>
<td>19 ms</td>
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<td>Saxophone Colossus</td>
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<td>4. “Now’s the Time”</td>
<td>Jamey Aebersold,</td>
<td>Ron Carter</td>
<td>Ben Riley</td>
<td>148 bpm (405 ms/beat)</td>
<td>Drums (78%)</td>
<td>17 ms</td>
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<td><em>Volume 6 – Charlie Parker</em></td>
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<td>Hi-hat lead</td>
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<tr>
<td>5. “Abdullah’s Delight”</td>
<td>Art Blakey,</td>
<td>Wendell Marshall</td>
<td>Art Blakey</td>
<td>175 bpm (343 ms/beat)</td>
<td>Drums (72.7%)</td>
<td>17 ms</td>
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<td><em>Orgy in Rhythm</em></td>
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Note: Average lead times are approximate based on a careful estimate of bass and cymbal onsets derived from waveform analysis using the software program Audacity.
bass leads were virtually identical to those for drum leads (55.3% and 55.1% respectively). More importantly, average scores for bass leads at fast tempos—244 bpm (“Tune Up”) and 199 bpm (“Work Song”)—were substantially higher with the recorded excerpts than with the synthetic examples employed in Experiment 1 (37.9%). The perceptual bias favoring drum leads found in Experiment 1 was apparently offset, suggesting that real on-top bass players employ some element in conjunction with timing to generate “push”—most likely some quality of timbre or attack lacking in the relatively undifferentiated synthetic samples.

Second, a small number of individual participants once again performed very well on this task, as was the case with Group 3 of Experiment 1 (i.e., those with the timing and assertion listening instruction). Most participants again scored no better than chance. However, a binomial test showed that the top four scores (three at 80%, one at 73.3%) were significantly better than chance ($p < .05$). Thus again, a small number of individuals (about 18% in this study), distinguished neither by music experience nor a stylistic preference for jazz, seem able to identify the lead instrument with some facility.

### Discussion

Average scores on the recorded examples used in this experiment were slightly better than scores for the synthetic examples employed in Group 3 of Experiment 1, but not significantly better than chance. Moreover, there seems to be little effect of learning. Repeated hearing of an individual excerpt did not lead to improved scores.

Participants performed considerably better in identifying bass leads here than in Experiment 1, however, suggesting a potential effect of timbre, attack, or some other quality in generating “push” in conjunction with timing. In this regard, the distinction observed by Keil (1966, p. 343) between “stringy” and “chunky” bass players is compelling. According to Keil, the former play with a “light, sustained, and basslike” sound; they pluck the strings high on the bass away from the bridge, “usually with the full side of the finger,” and the sound of each tone “emerges.” By contrast, the latter play with a “heavy, percussive, and drumlike” quality; they pluck the strings near to the bridge, generally with the tip of the finger, and the tone seemingly “bursts.” Listeners might be more inclined to interpret a “chunky” bass sound—i.e., one with a more rapid rise time—as more assertive; they might consequently have more facility identifying “chunky” bass leads. Quality of timbre and attack were not controlled for in this experiment, however, and the relative “stringiness” or “chunkiness” of the bass players included on the recorded excerpts is very much open to interpretation. Further research is needed to determine the effects of timbre and attack on perception of timing.

Most participants’ identification of bass or drum leads was no better than chance. A few (18%) performed at levels exceeding chance, however, which corroborates the finding from Experiment 1 that a small number of individuals appear to be able to perceive the temporal discrepancy between bass and drums with some facility when instructed to listen for both timing and assertion together. Neither music training nor stylistic preference seems to account for this, however. Rather, it may reflect a greater perceptual acuity for temporal discrimination among these individuals or use of a more coherent listening strategy for detection of the asynchrony.

### General Discussion

The two experiments presented here offer little support for the central claims of PD theory. Taken together, they show that most ordinary listeners, irrespective of music training or stylistic preference, are unable to discern a discrepancy of 30 ms or less between bass and drums in the jazz rhythm section with any consistency across a
range of tempos and timing values, whether listening explicitly for timing or for the quality of assertion or drive it is thought to produce. They do have marginally more success when listening for timing and assertion together, irrespective of the width of the asynchrony—but not enough to support the assumption of PD theory that it is the microrhythmic push and pull between bass and drums in their articulation of the beat that generates the engaging rhythmic quality we call swing.

It is likely, of course, that detection rates would improve with either the “timing” or “both” listening strategies if the onset asynchrony were increased above 30 ms. Further experiments are needed to determine a minimum threshold asynchrony at which a majority of participants is able to identify the lead instrument at better than chance levels, and to evaluate whether or not the quality of assertion is more or less salient at wider discrepancies. This was not done in this study, which sought instead to model jazz performance practice as much as possible in order to test the validity of the claims of PD theory. Extent research has shown that discrepancies between bass and drums in the jazz rhythm section are rarely sustained above 30 ms for more than two or three consecutive beats, most likely because larger discrepancies move beyond the range of expressive nuance and tend to sound more like errors than expressive deviations from synchrony.

Based on the results of Experiment 1, when listening for timing and assertion together, listeners have more success in perceiving drum leads than bass, especially at faster tempos. Analysis of false-alarm and hit rates indicates that this is an effect of perceptual bias, however, perhaps suggesting a tendency for listeners to attend primarily to the pulse of the drummer. It appears from Experiment 2, however, that qualities of timbre and attack can potentially offset this bias, leading to improved facility identifying bass leads. Additional research is needed to evaluate the effects of timbre and attack on the perception of bass leads. It may be that listeners make judgments about assertion or “push” on the basis of timing for drums, but timbre or attack for bass.

Experiment 2 shows further that listeners fare no better at detecting bass or drum leads with recorded performances of real jazz musicians than with synthetic excerpts. Moreover, hearing a passage multiple times does not improve performance.

Do “the gaps, large or small,” between bass and drums in their shared articulation of the beat indeed “provide the push or layback feel of a particular performance,” as Prögler (1995) claims? If so, we would expect listeners to have had more success employing the assertion strategy in Experiment 1, but their average scores for this listening strategy were not better than chance. In general, the assertion strategy proved to be ineffective; assertiveness does not appear to be a very salient effect of the asynchrony.

Nevertheless, the fact that a small set of participants in this study (14-18%) were able to perceive the discrepancy with some facility when listening for both timing and assertion together—but not when listening for either alone—suggests that timing discrepancies can be successfully perceived in terms of “push,” but only when that is specifically what one is listening for. In other words, “push” is there only when one is listening for it as an effect of timing, and not as a more general effect—and only for a small percentage of listeners. Further research is needed to explain these individuals’ success, which appears unrelated to either formal music training or a preference for any particular style of music.

What this suggests is that the expressive effects of PDs between bass and drums, though not negligible, are relatively modest, minimally salient, and not likely the central force behind the production of the highly engaging rhythmic quality we call swing. The inability to perceive PDs between bass and drums accurately within the range of expressive nuance does not necessarily mean they have no effects at all or that they are irrelevant in the production of “engendered feeling”; it only means that their significance has likely been overstated in the PD literature, and that they probably do not do exactly what PD theorists think they do. What is at issue is whether or not timing discrepancies actually “create swing,” as Keil and other PD theorists propose—whether or not PDs suffice to produce “engendered feeling.” If one judges swing by the spontaneous impulse of listeners to tap their feet, snap their fingers, or bob their heads (Schuller, 1989, p. 223), or by “how crowded a dance floor becomes during a performance and from the heightened emotional responses from the participants” (Washburne, 1998, p. 161), we can only conclude from these experiments that, because of their minimal perceptual salience, participatory discrepancies play a rather marginal role in this process. Because their effects—Prögler’s “push” or “layback” feels—cannot be brought reliably to the level of conscious awareness except by a small minority of individuals distinguished neither by formal music training nor musical taste, there is no reason to believe that PDs are themselves exclusively or even predominantly responsible for the production of swing. There is simply insufficient evidence that asynchronous timing between bass and drums engenders “a productive tension . . . which is central to swing” (Prögler, 1995, p. 22), no evidence that any such tension is readily available to perception for most
listeners, and consequently, no evidence that PDs perform the work that PD theory expects them to do.

*Participatory Discrepancies in Performance*

This calls into question a fundamental distinction assumed in PD theory: the opposition between the syntactical and subsyntactical domains of rhythmic experience—or to put it differently, the opposition between structure and process. In PD theory, it is not *syntactical structures*—those things that can be represented in musical notation—that produce engendered feeling; it is rather *subsyntactical processes* that are thought to do so in the form of expressive microtiming. But what is missing from Keil’s framework, indeed what seems to be a fundamental flaw in his critique of Leonard Meyer’s (1956) work, is the recognition that there are in fact *syntactical processes* that are very much at play in producing “vital drive.” In other words, there is no reason to assume that dynamic qualities of feeling do not emerge from the syntactical shape of a well timed, repeating groove pattern. For example, Butterfield (2006) proposes that engendered feeling in jazz and other groove-based musics stems primarily not from PDs, but from the syntactical configuration of rhythmic patterns played in the rhythm section—a configuration that generates considerable forward momentum from the operation of anacrusis across multiple levels of rhythmic structure, especially on the backbeats. The effects of expressive timing—specifically, subsyntactical deviations from isochrony in the maintenance of the beat—are secondary; they serve either to enhance or attenuate “the power of anacrusis” generated at the syntactical level.

The difficulty most listeners have in hearing and responding to PDs also raises the question of how jazz musicians produce and engage them. We might expect musicians who normally fulfill a timekeeping function in an ensemble to have a greater perceptual acuity than others with respect to timing, and at least one empirical study has verified that good rhythm-section players sustain consciously. Finally, they also clarify how individual musicians acquire a particular timing profile. Consequential and systematic character also have been proposed. In a review of studies of this nature, Collier and Collier have suggested that mechanical or ergonomic lags, which involve the physical processes of note production on a given instrument, can affect a musician’s timing with respect to the beat (1996a, pp. 126-128, 134). Collier and Collier also observe acoustic lags that result from the different rise times characteristic of different instruments.

Iyer (2002) has described various perceptual lags that may also be at play in generating PDs. Synchronization often cancels out or “masks” perception of two or more distinct voices or instruments, as his MIDI-generated audio examples affirm (Iyer, 2002, pp. 400-401, audio examples 403-406 and figures 401 and 402). A simpler test is possible, however: clapping in perfect synchrony with the beat of a metronome will mask its sound. Sustaining such synchrony for more than about ten consecutive beats is quite difficult, in fact, since perfect timing can only be confirmed negatively by the absence of the metronome’s click in perception. Paradoxically, then, a slight microrhythmic displacement enables us to confirm that we are indeed clapping “with” the metronome, that we are “together.” From this, we can infer that musicians might unconsciously situate their beats where they can best hear themselves in relation to others. Similarly, Iyer proposes that “[t]iming variations can allow an instrument that is sonically buried to draw attention to itself in the auditory scene” (2002, p. 402)—a tendency also well documented in studies of melody leads (Palmer, 1989, 1996).

These various types of delay or lags each can contribute to the production of participatory discrepancies independent of a performer’s intentions. Moreover, they offer viable explanations for the systematic character of such discrepancies, especially since microrhythmic variation is so difficult to perceive and to achieve and sustain consciously. Finally, they also clarify how individual musicians acquire a particular timing profile that characterizes their own style—a distinct rhythmic feel that is not necessarily the product of conscious intention, but which may simply be a function of their own more or less unique cognitive strategies and the more or less idiosyncratic ways in which they get around their instruments.

Even as these factors generate PDs between bass and drums, it is nevertheless extraordinary how very small the average discrepancy between their onsets tends to be in their maintenance of the pulse. Research on
sensory-motor synchronization may help explain the narrow asynchrony range. When performing a sensory-motor synchronization task, such as tapping along with an isochronous tone sequence, participants show greater sensitivity to timing deviations than when making perceptual judgments in the absence of such movement (Repp, 2000a, 2000b). Of particular relevance is their rapid adaptation to phase shifts—the lengthening or shortening of a single IOI in an otherwise isochronous tone sequence. Participants generally compensate for the phase shift within two or three taps of the perturbation when performing a sensory-motor synchronization task. This is true even with subliminal phase shifts—those in which the perturbation falls beneath the 20 ms perceptual detection threshold for temporal order identified by Hirsh (1959). In other words, phase error correction in sensory-motor synchronization is not limited by the temporal order threshold. It nevertheless has been shown to be a low-level automatic process, and not a high-order cognitive function; i.e., subliminal phase error correction is not a product of conscious intention (Repp, 2005, pp. 979-981).

What this suggests is that, because they are engaged in a sensory-motor synchronization task, jazz bassists and drummers will tend to keep to a minimum the asynchronies between their quarter-note onsets. Any discrepancy generated between them, even one beneath the temporal order threshold, will generally be compensated for within two or three beats and brought back to within a baseline average asynchrony, irrespective of the conscious intentions of the performer.

An Alternate Proposal

I would nevertheless argue for the potential of conscious intention in generating PDs between bass and drums, though their expressive effects must be understood as more limited and local than previously thought. The overreaching claims of PD theory with respect to the effects of beat timing stem largely, I believe, from confusion as to the actual nature of that beat. The PD framework stipulates a relatively flexible beat, one that “breathes,” against which bass and drums vary their onset timings to a substantial and consequential degree in order to drive the groove. As we have seen, however, the discrepancy between their onsets is usually less than about 20 ms and thus typically passes beneath the temporal order threshold. Moreover, Collier and Collier’s exhaustive study of jazz tempos revealed the astonishing regularity and precision of the beat over the course of any given performance (1994; see also Collier, 1993, pp. 79-88). Tempo shifts tend to be minute, rarely exceeding five percent, and tend to occur only at major structural junctures, such as the “bridge” in an AABA form, or with the entrance of a particular soloist.

Rose (1989) did report local deviations in beat durations. Specifically, the musicians in his study tended to sustain beats 2 and 4 about 5% longer than beats 1 and 3 on average when playing a moderate swing groove with a tempo of about 132 bpm (1989, pp. 77-84, 106-108). This suggests not a flexible beat that “breathes,” however, but a tendency for these musicians to hit the backbeats slightly on top of the beat, an effect that enhances the “power of anacrusis” generated at the syntactical level (Butterfield, 2006, paragraphs 24-34). Moreover, Rose found that larger formal units, such as 8-bar phrases, tended to be strikingly uniform in total duration, which suggests an underlying near-isochronous pulse instead of the more flexible beat of PD theory (1989, pp. 96-97).

Clearly, then, the central value in jazz timekeeping is not a beat that “breathes,” but simultaneity between bass and drums in their maintenance of a rigorously steady pulse without perceptible deviations from isochrony. It is only against this precision, I believe, that PDs can be activated for expressive purposes, and only for limited spans of time. The mechanisms by which this is accomplished are best illuminated by recent research in music perception that regards musical meter as a “form of entrainment behavior” (London, 2004, p. 6).

In an entrainment model, there is no abstract beat that is objectively present apart from the real events that draw its perception into being. Instead, listeners extract from a musical surface a “pattern of invariance” and “entrain” to it—i.e., they synchronize an internal, self-sustaining oscillatory mechanism with an external rhythmic signal whose period is more or less regular. These internal oscillations are driven by the external event’s rhythm and serve to “generate expectancies that enable anticipation of future aspects of an event” (Large & Jones, 1999, p. 123). What we experience as a beat is the synchronizing of our attentional focus around a more or less precise moment of expectation, what Large and Palmer call a “region of sensitivity” within the cycle of the external rhythm. We perceive as beats those event onsets that arrive within this region, “whose peak or maximum value corresponds to where the beat is expected” (2002, p. 7). The width of this region, which represents the durational span of a listener’s attentional focus, is variable and depends on the coherence and consistency of the external driving rhythm. A more regular rhythm leads to a narrowing of the listener’s attentional focus and the targeting of “attentional energy” around sharp peaks of expectation,
a more definite sense of what counts as an expression of the beat, and greater accuracy in predicting and attending to rhythmically anticipated events. By contrast, a less regular rhythm induces a wider attentional focus and a dispersion of attentional energy around more diffuse and nebulous spans of expectation, less certainty about the moment of the beat’s expected arrival, and less accuracy in attending to rhythmically anticipated events.

Event onsets that occur within the region of sensitivity but do not coincide precisely with the expectancy peak induce listeners to readjust the phase and period of the internal oscillator, thereby assimilating such events to their experience of the beat (Large & Palmer, 2002, p. 7). This is what allows us to accommodate variably timed events to our sense of the prevailing meter. But any such adjustment “rests on a reactive shift of the attentional focus in time,” which prompts a distinction between “reactive” and “anticipatory” attending:

Anticipatory attending is shown to realize a temporal expectancy, set in motion by the prevailing rhythm, that is directed toward a future (expected) point in time. By contrast, reactive attending involves a re-orientation toward an unexpectedly timed item that follows from a violation of this expectancy. In short, reactive attending is contingent upon temporal expectancies, i.e., upon anticipatory attending, because it is sparked by an expectancy violation. (Jones, Johnston, & Puente, 2006, p. 63)

Our experience of expressive timing is largely a manifestation of reactive attending. Any sense of “early” or “late” with respect to the beat stems from the perception of a deviation from the moment of that beat’s expected arrival, a moment that is more or less specific depending on the coherence of the driving rhythm—i.e., its regularity—and hence the efficiency of anticipatory attending. The narrower the attentional focus around well defined peaks of expectation, the narrower the span of what will be perceived as “on time” and the greater the salience of any expressive deviation perceived as “early” or “late” as a consequence of reactive attending.

What jazz musicians gain from the near-isochronous pulse maintained by bass and drums and the near-simultaneity of their beat onsets is highly efficient anticipatory attending and reactive attending sensitive to very small deviations in timing. This presents an opportunity primarily for improvising soloists to generate PDs against the beat of the rhythm section for expressive purposes. Soloists tend to lag behind the rhythm section’s beat by about 50–80 ms at most jazz tempos, a discrepancy large enough to produce the effect of the “laid back” soloist (Friberg & Sundström, 2002, pp. 340–345). Nevertheless, “the soloist whose phrasing is consistently behind the pulse and then for one dramatic instant squarely on top of it” strategically imparts more energy to the becoming of a phrase (Keil, 1966, p. 346).

Consider the passage shown in Example 2, drawn from Red Garland’s improvised piano solo on “Spring Will Be A Little Late This Year.” Garland is accompanied by Paul Chambers on bass and Art Taylor on drums. Several figures pertaining to the timing of onsets on the quarter-note downbeats for each instrument are shown in Table 4. (Onsets for each instrument were derived from the same procedure described for Experiment 2, above.) Taylor performs the ride rhythm using brushes on the snare drum and maintains a tempo of about 146 bpm. The overall average IOI between his quarter-note downbeats is 410 ms, but his beats 1 and 3 have slightly smaller average IOIs than his beats 2 and 4—a tendency also documented in Rose (1989, pp. 80–81) and addressed in Butterfield (2006)—indicating that Taylor has a tendency to anticipate the backbeat attacks on the hi-hat cymbal.

The timing profile for bass is comparable to that of drums, though beat 3 in the bass appears to be a little shorter on average and beat 4 a little longer. This is reflected in the figures for average downbeat latency, a measure of how far behind the onset of the drummer Chambers is on each beat. The bass lags an average of 16 ms behind the beat of the drums. The latency for beat 4 is less than for the other beats, however, indicating a possible tendency for Chambers to attack this slightly earlier than the other beats. At any rate, the average discrepancy between bass and drum onsets for each beat in this passage is less than 20 ms. This, in conjunction with the very low standard deviations for each beat, indicates a very tight coordination of the quarter-note pulse between them and the generation of an exceptionally coherent driving rhythm that will likely induce highly efficient anticipatory attending in the listener.

Against the stable backdrop provided by bass and drums, Garland’s timings on piano vary substantially, as indicated in Table 4 by the relatively high standard deviations in his quarter-note IOIs for each beat. The average

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4Red Garland, “Spring Will Be A Little Late This Year,” from All Kinds of Weather, Prestige 7148 (1958).
Example 2. Participatory discrepancies in the piano solo line in Red Garland’s “Spring Will Be A Little Late This Year” (*All Kinds of Weather*, Prestige 7148, 1958). Red Garland, piano; Paul Chambers, bass; Art Taylor, drums. Downbeat latency figures above the staff show lag in ms between drum onsets and piano on each quarter-note downbeat. Eighth notes are swung.

Table 4. Timing Figures for Example 2, An Excerpt From Red Garland’s “Spring Will Be A Little Late This Year.”

<table>
<thead>
<tr>
<th></th>
<th>Beat 1</th>
<th>Beat 2</th>
<th>Beat 3</th>
<th>Beat 4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drums:</strong></td>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td>average quarter note IOIs</td>
<td>406</td>
<td>10</td>
<td>414</td>
<td>7</td>
<td>406</td>
</tr>
<tr>
<td><strong>Bass:</strong></td>
<td><strong>average quarter note IOIs</strong></td>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
</tr>
<tr>
<td>average quarter note IOIs</td>
<td>408</td>
<td>25</td>
<td>416</td>
<td>20</td>
<td>408</td>
</tr>
<tr>
<td><strong>Piano:</strong></td>
<td><strong>average downbeat latency</strong></td>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
</tr>
<tr>
<td>average downbeat latency</td>
<td>17</td>
<td>13</td>
<td>15</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td><strong>Piano:</strong></td>
<td><strong>average downbeat latency</strong></td>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
<td><strong>Mean</strong></td>
<td><strong>SD</strong></td>
</tr>
<tr>
<td>average downbeat latency</td>
<td>46</td>
<td>17</td>
<td>49</td>
<td>10</td>
<td>53</td>
</tr>
</tbody>
</table>

*Note: Downbeat latency figures indicate ms bass and piano onsets lag behind drum onsets on each quarter-note downbeat.*
IOIs for his beats 1, 2, and 3 correspond quite closely to those of Taylor on drums, but his beat 4 tends to be shorter. This, again, is a consequence of downbeat latency: Garland tends to lag more and more with each beat over the course of the bar—a tendency that can be seen in mm. 1, 3, 4, and 5 of Example 2. Because he usually delays beat 4 more than the ensuing beat 1, his beat 4’s tend to be shorter in duration than those of the drummer.

The degree of downbeat latency is also quite substantial (51 ms on average), and its variation over the course of the passage generates subtle expressive effects. Of particular interest is Garland’s treatment of triplets. In m. 2, he arrives 51 ms behind the onset of the drummer on beat 2, but then arrives on beat 3 only 27 ms behind, indicating a slight acceleration through the triplets on beat 2. He does not accelerate the triplets on beat 4, however, but remains about 40 ms behind the drummer’s beat. In other words, these triplets are slower than those of beat 2, perhaps reflecting the imminent ending of his phrase.

By contrast, Garland decelerates a bit through the triplets in m. 7, and this has an interesting effect in the context of the phrase as a whole. The staircase-like melodic pattern in m. 6 emphasizes the quarter-note level of pulsation and a slow stepwise ascent from C♭5−D♭5-E♭5 in half notes. This gives way in m. 7 to a rapid burst up the octave to the D6 and a shift into shorter note values (i.e., eighth note triplets and swing eighth notes), both of which generate an intensification of energy and forward propulsion. The increase in downbeat latencies through the first half of this bar gently attenuates this energy, however, and this minute deceleration allows for dramatic emphasis on the D6, the melodic climax of the phrase.

To the extent that these timing differentials generate expressive effects, they stem from reactive attending dependent on efficient anticipatory attending. In other words, these effects depend on the coherence and consistency of a well defined beat, which is clearly provided by Chambers and Taylor in this passage. Widening the gap between bass and drum onsets compromises the power of PDs for soloists, for it leads to a less defined beat, and thus less efficient anticipatory attending and an attenuation of the expressive effects of playing on top of or behind that beat. Indeed, it can present fundamental problems for soloists trying to time melodic eighth notes in relation to the rhythm section’s quarter-note pulse:

“When you have different guys in the rhythm section playing on different parts of the beat,” laments trumpeter Jimmy Robinson, “they’re going to be fighting each other constantly, and it’s very difficult to solo against that” (quoted in Berliner, 1994, p. 413).

There are nevertheless limited conditions under which PDs between bass and drums can be effective. One instrument may provisionally play the principal timekeeping role, generating efficient anticipatory attending while freeing the other up to move around the beat for expressive purposes. If the maximum sustainable discrepancy between bass and drums is about 30 ms, movement by the “free” instrument from one “side” of the beat to the other entails a potential shift of up to 60 ms in that instrument’s timing of the beat, as well as a 30 ms shift in the phase of the beat’s cycle (i.e., the beat suddenly arrives up to 30 ms earlier or later)—deviations large enough to register subtle expressive effects at most jazz tempos. If this instrument moves from the back to the top of the beat while the other instrument maintains a steady pulse, it moves into a position of greater prominence within the auditory scene—it draws more attention to itself and, as an outcome of reactive attending, suggests the potential for an increase in tempo, thereby imparting more energy to the groove which may be experienced in terms of “push.” If, by contrast, the “free” instrument moves from the top to the back of the beat while the other instrument maintains a steady pulse, it draws less attention to itself—it risks being buried due to the effects of masking—but it does exert a slight drag on the tempo, a feeling of laying back that serves to diminish the energy of the groove. Such movement can be incidental or the product of conscious intention, as when either bassist or drummer decides actively to push the beat or to lay back on it. Or it may arise simply from a decision to move into the foreground of the musical texture, a move that is typically cashed out unconsciously with a shift towards the front of the beat, similar to the tendency of classical pianists to lead with the melody (Palmer, 1989, 1996).

Example 3, a transcription of a short passage featuring bass and drums alone on Sonny Rollins’s “Blue 7,” provides a brief illustration of this process.3 The excerpt shown is mm. 5-12 of the second chorus of a 12-bar blues in the key of B♭. Prior to this point in the performance, Max Roach had provided only hi-hat backbeats on the drum kit; here, he adds the ride rhythm played on the ride cymbal, as shown. Roach leads bassist Doug Watkins on 91% of the 32 beats shown here, performed at a tempo of about 132 bpm. Several figures pertaining to the timing of onsets on the quarter-note downbeats for each instrument are shown in Table 5.

3Sonny Rollins, “Blue 7,” from Saxophone Colossus, Prestige OJCCD-291-2, (1956). Onsets for each instrument were again derived from the same procedure described for Experiment 2, above.
TABLE 5. Timing Figures for Example 3, An Excerpt from Sonny Rollins’s “Blue 7.”

<table>
<thead>
<tr>
<th></th>
<th>Beat 1</th>
<th></th>
<th>Beat 2</th>
<th></th>
<th>Beat 3</th>
<th></th>
<th>Beat 4</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Drums: average quarter note IOIs</td>
<td>440</td>
<td>7</td>
<td>466</td>
<td>4</td>
<td>436</td>
<td>3</td>
<td>459</td>
<td>5</td>
<td>450</td>
</tr>
<tr>
<td>Bass: average quarter note IOIs</td>
<td>437</td>
<td>9</td>
<td>461</td>
<td>19</td>
<td>439</td>
<td>6</td>
<td>460</td>
<td>10</td>
<td>449</td>
</tr>
<tr>
<td>Bass: average downbeat latency</td>
<td>22</td>
<td>14</td>
<td>19</td>
<td>16</td>
<td>15</td>
<td>16</td>
<td>20</td>
<td>13</td>
<td>19</td>
</tr>
</tbody>
</table>

Note: Downbeat latency figures indicate ms bass onsets lag behind drum onsets on each quarter-note downbeat.

As with the Red Garland passage shown in Example 2, beats 1 and 3 are typically shorter in duration than beats 2 and 4, indicating a tendency in both instruments toward on-top timing of the backbeats.

Roach maintains the steadier quarter-note pulse, as indicated by the very low standard deviations for each beat; he is in the principal timekeeping role here. By contrast, Watkins moves more freely around the beat. His average latency is about 19 ms, but it ranges from a high of 42 ms behind the drummer’s beat to a low of 16 ms on top, as shown below each note in Example 3. Watkins lags substantially through mm. 5-6, but then catches up briefly as his bass line rises chromatically in m. 7. He then lays back again by as much as 40 ms until m. 11, where he moves into the lead while elaborating the tonic in the final two bars of the chorus. Between beats 2 and 3 in m. 11, Watkins moves from 25 ms behind Roach to 9 ms ahead—a shift of 34 ms. More broadly, from the beginning of m. 11 to beat 2 of m. 12, Watkins moves from 38 ms behind to 16 ms ahead, a shift of 54 ms. These shifts, I propose, are large enough to generate a subtle boost of energy just prior to Sonny Rollins’s entrance on saxophone at the end of m. 12, an effect made possible only against the stable attending framework established by Max Roach’s remarkably steady pulse on the ride cymbal.

Thus it is not the stable configuration of a discrepancy between bass and drums that generates expressive effects; it is rather movement out of one configuration into another. The effects of this movement are limited in duration, however. Within a few beats, phase correction will inevitably settle in as a consequence of reactive
attending. Listeners and performers alike will spontaneously adjust their internal oscillators to adapt to the new timing configuration, and the qualities of “push” or “layback” derived from the change of configuration will steadily diminish.

This helps to clarify some of the evocative descriptive statements jazz rhythm section players have made about their experiences with respect to timing. Bassist Rufus Reid, for example, alludes to “an edge I feel when I’m playing walking bass lines on top of the beat. It’s like if you are walking into the wind, you feel a certain resistance when your body is straight, but you feel a greater resistance if you lean into the wind” (quoted in Berliner, 1994, p. 351). Similarly, another bass player interviewed by Berliner “likens his experience to steadying a boat’s course on a rough sea by holding the mainsail taut against the wind” (p. 396). These are experiences that make sense as momentary deviations against a normative timing framework. The bass player who typically leads a drummer by about 20-30 ms defines the norm rather than resisting it—he or she does not likely experience this as “walking into the wind.” By contrast, the bassist who typically lags to the same degree probably does experience some kind of resistance when moving into the lead role at a significant moment in the chord progression. But staying there for more than a few beats will result in a loss of the effect since performers and listeners alike will quickly adapt, leading to the establishment of a new timing norm.

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“In its simplest physical manifestation,” writes Gunther Schuller, “swing has occurred when, for example, a listener inadvertently starts tapping his foot, snapping his fingers, moving his body or head to the beat of the music” (1989, p. 223). Evidently, the way musicians “pull against the pulse” has little impact on prompting such responses. The experiments presented here provide scant evidence to support the claim of PD theory that asynchronous timing between bass and drums in the jazz rhythm section drives the groove and is exclusively or even predominantly responsible for generating the engaging rhythmic quality we know of as swing. Indeed, to my knowledge, no such evidence has ever been presented, nor has anyone explained the precise mechanism by which this is purportedly accomplished.

The entrainment model outlined above suggests that PDs provide little more than momentary expressive effects in relation to an otherwise near-isochronous pulse sustained in near-synchronicity between bass and drums. PDs generate qualities of “push” or “layback” only for brief periods as an outcome of movement by one of these instruments from one side of the beat to the other, an effect stimulated by reactive attending, itself dependent on efficient anticipatory attending, but steadily extinguished through the adaptive adjustment of a listener’s internal entrainment mechanisms. Given this limitation on their effects, what PDs between bass and drums offer is not the production of swing itself, but a subtle means of enhancing or attenuating the forward momentum of a swing groove for strategic purposes—momentum that is likely generated by a variety of rhythmic processes at the syntactical level. Further research is needed to test the sensitivity of listeners to changes in the timing configuration between bass and drums. How salient, for example, is the affect generated by a change in lead? Is “push” easier to perceive than “layback”? Does one instrument produce a stronger effect than the other when moving into or out of the lead?

It seems a mistake to imagine that a phenomenon as complex, mysterious, and intractable as swing can be explained by means of any one process. Surely many factors enter into the judgment of jazz musicians and their fans when they describe a performance as swinging. Syntactical features undoubtedly contribute something to the production of engendered feeling—the ding-ding-a-ding pattern of the drummer’s ride rhythm generates forward momentum independent of the operation of expressive timing. Variations in any musician’s swing ratio produce varying qualities of motional energy in relation to phrase structure. The way in which soloists lay back against the beat of the rhythm section also contributes important qualities of feeling to the mix. Blues inflection, timbre, instrumentation, even the character of an ensemble arrangement all factor into judgments of whether or not a particular band swings. This is to say nothing of the qualities of feeling that emerge from effective social-interactive play among the members of a rhythm section in their ongoing negotiation of the beat.

All this suggests that we might profitably construe swing less as a specific quality of feeling engendered by specific rhythmic processes than itself a process for generating rhythmic feeling. In other words, swing as an outcome, something that can be defined and explained, is less important than swing as a practice. In this regard, PDs between bass and drums constitute but one expressive resource among many—one strategy for swinging, as it were. Their effects are generally secondary to the more consequential effects that emerge from events that take place at the syntactical level, but they are by no means inconsequential as a resource for swinging through a compelling groove.
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